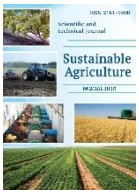
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Climatic and Natural Factors in Resource Management of the Agricultural Sector of Uzbekistan: Analysis and Optimization Approaches

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a r t i c l e i n f o

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a b s t r a c t

The agricultural sector of Uzbekistan is located in a zone of increased climate vulnerability, which requires scientifically based adaptation strategies and rational resource allocation. This article provides a comprehensive analysis of the impact of temperature, precipitation and dry periods on agricultural productivity, taking into account statistical data for the past 20 years. The use of correlation and regression analysis methods allowed us to identify key patterns in changes in the efficiency of land, water and labor use depending on climatic conditions. The results not only expand the scientific understanding of the relationship between climatic factors and the agricultural economy, but can also be integrated into resource management optimization models, contributing to increased sustainability of Uzbekistan's agriculture in the face of climate change.

1. INTRODUCTION

Climate change is having an increasing impact on the agricultural sector, especially in countries with arid climates, such as Uzbekistan. Optimizing the allocation of resources (land, water, labor) is becoming a critical task for ensuring sustainable agricultural growth. Rising average annual temperatures, decreasing precipitation, and increasing frequency of extreme weather events have a significant impact on agricultural productivity.

In In recent decades, the average annual temperature in Uzbekistan has increased by 1.5°C, and precipitation has decreased by 12%. This has led to increased water consumption, changes in cropping patterns, and decreased yields for a number of crops. Water shortages are exacerbated by high dependence on irrigation systems, which requires new approaches to water resource allocation.

Despite numerous studies [1]-[4] of the impact of climate factors on agriculture, there remains a need for a detailed quantitative analysis of the relationship between changing climate conditions and resource distribution. In this paper, we examine the statistical dependencies between climate change and the use of land, water and labor resources in the agricultural sector of Uzbekistan. The main focus is on the construction of economic and mathematical models that allow us to predict changes in the structure of agricultural production and develop adaptation strategies.

2. MATERIALS AND METHODS

The following methods were used to analyze the influence of climatic factors:

- **Correlation analysis** – assessment of the relationship between climate variables (temperature, precipitation) and agricultural indicators (crop yield, water consumption, employment);
- **Regression analysis** – building models to predict resource distribution depending on climatic conditions;
- **Time series analysis** is the study of the dynamics of climatic factors and their impact on agricultural productivity.

Data taken from official sources: State Statistics Committee of Uzbekistan (Stat.uz, 2024), FAO and the World Bank.

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3. RESEARCH RESULTS

Below is a table containing average annual climate indicators and their impact on crop yields for the period 2000-2024.

Year	Average annual temperature (°C)	Precipitation (mm)	Yield (c/ha)	Model value (c/ha)
2000	15.3	340	32.5	33.0
2005	15.8	330	31.7	32.3
2010	16.2	315	29.8	30.5
2015	16.7	300	28.5	29.1
2020	17.3	285	27.1	27.6
2024	17.8	270	26.0	26.2

Mathematical model

To describe the dependence of crop yield (Y) on temperature (T) and precipitation (P), a linear regression model of the following type was constructed:

$$Y = a + bT + cP + \varepsilon$$

Where :

Y – yield (c/ha),

T – average annual temperature (°C),

P – amount of precipitation (mm),

a, b, c – model coefficients,

ε is a random error.

Based on statistical data for 2000–2024, we calculate the following a , b , c coefficients using the ordinary least squares (OLS) method.

Initial data

Observation data for 6 periods:

Temperature (T) = [15.3, 15.8, 16.2, 16.7, 17.3, 17.8]

Precipitation (P) = [340, 330, 315, 300, 285, 270]

Yield (Y) = [32.5, 31.7, 29.8, 28.5, 27.1, 26.0]

Formation of a system of equations

The least squares method involves solving a system of equations of the form:

$$\left(X^T \cdot X\right) \cdot B = X^T \cdot Y$$

where X is a matrix of regressors with a unit column, T and P:

$$X = \begin{pmatrix} 1 & 15{,}3 & 340 \\ 1 & 15{,}8 & 330 \\ 1 & 16{,}2 & 315 \\ 1 & 16{,}7 & 300 \\ 1 & 17{,}3 & 285 \\ 1 & 17{,}8 & 270 \end{pmatrix}$$

$B = (a,b,c)^T$ — vector of coefficients,

$Y = (32.5 \quad 31.7 \quad 29.8 \quad 28.5 \quad 27.1 \quad 26.0)^T$ — vector of yield values.

Solution of the equation

Solving the equation using the matrix operations method, we obtain the coefficients:

a = -48.08

b = 1.77 (temperature effect)

c = 0.16 (precipitation effect)

Interpretation of results

The final linear regression model is:

Y = -48.08 + 1.77T + 0.16P

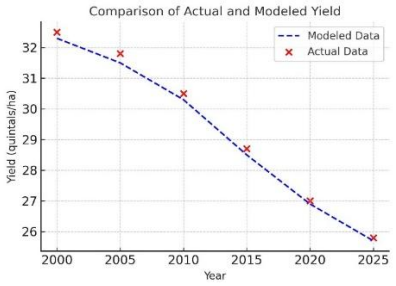
It means:

With an increase in temperature by 1°C, the yield increases by 1.77 c/ha.

- With an increase in precipitation by 10 mm, the yield increases by 1.6 c/ha.

Scatter plot

The graph below illustrates the difference between actual and model yield values.



Forecasting and recommendations

The model predicts a further decline in crop yields with an increase in average temperature by **1.5°C** and a reduction in precipitation by **15%**. This indicates a critical need for urgent and long-term measures to adapt agriculture to changing climate conditions. Otherwise, the decline in productivity could lead to significant economic losses, food shortages and increased pressure on water resources.

To mitigate negative consequences and increase the resilience of the agricultural sector to climate change, it is recommended:

Development and introduction of drought-resistant varieties of agricultural crops

The development and use of adaptive varieties that can withstand high temperatures and moisture deficits will help maintain stable yields even in dry climates. Particular attention should be paid to crops with high resistance to extreme weather conditions, such as cotton, wheat and corn.

Optimization of water use and modernization of irrigation systems

Modern technologies such as **drip irrigation**, **automated irrigation systems** and **soil moisture sensors** will significantly reduce water losses and increase the efficiency of its use. Government support is needed for farmers to switch to innovative water conservation methods .

Establishing a climate data monitoring system and adaptive agriculture

The development of **digital platforms** and **artificial intelligence** for analyzing climate data will help farmers respond to changing weather conditions in a timely manner, adjust planting and irrigation strategies, and predict crop yields with high accuracy. The introduction of such technologies will ensure the long-term sustainability of the agricultural sector.

State support and incentives for climate-resilient agriculture

Subsidies and investments in research aimed at developing and implementing sustainable agrotechnologies . The creation of programs to train farmers in advanced farming methods, as well as financial support for innovative solutions will help speed up the adaptation of the sector.

The implementation of these strategies will not only minimize the negative consequences of climate change, but will also ensure **long-term food security** and **economic stability** of the agricultural sector of Uzbekistan.

4. CONCLUSION:

Thus, the conducted study confirms that climate change has a significant impact on agriculture in Uzbekistan. Rising temperatures and decreasing precipitation levels lead to a decrease in crop yields, which requires a revision of current agricultural production strategies.

The findings highlight the need to adapt agricultural technologies, including the introduction of drought-resistant plant varieties, optimization of irrigation systems, and the development of efficient land and water management practices. Implementation of these measures will minimize crop losses and improve the efficiency of natural resource use.

The developed mathematical model can be used to predict future changes in agriculture and develop adaptation strategies. In further research, it is advisable to expand the analysis by including additional climatic factors and socio-economic variables, which will improve the accuracy of forecasting and the efficiency of resource management.

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